ORIGINAL ARTICLE

Does deep water running reduce exercise-induced breast discomfort?

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Aim: To establish whether exercise-induced vertical breast displacement and discomfort in women with large breasts were reduced during deep water running compared to treadmill running.
Methods: Sixteen women (mean age = 32 years, range 19–43 years; mean mass = 74.1 kg, range 61–114 kg; mean height = 1.7 m, range 1.61–1.74 m), who were professionally sized to wear a C+ bra cup, were recruited as representative of women with large breasts. After extensive familiarisation, vertical breast motion of the participants was quantified as they ran at a self-selected stride rate on a treadmill and in 2.4 m deep water. Immediately after running, the subjects rated their breast discomfort and breast pain (visual analogue scale) and their perceived exertion (Borg scale). Breast discomfort, breast pain, perceived exertion, vertical breast displacement and vertical breast velocity were compared between the two experimental conditions.
Results: Exercise-induced breast discomfort was significantly less and perceived exertion was significantly greater during deep water running relative to treadmill running. Although there was no significant between-condition difference in vertical breast displacement, mean peak vertical breast velocity was significantly ($p<0.05$) less during deep water (upward mean (SD): 29.7 (14.0) $cm.s^{-1}$; downward: 31.1 (17.0) $cm.s^{-1}$) compared to treadmill running (upward mean (SD): 81.4 (21.7) $cm.s^{-1}$; downward: 100.0 (25.0) $cm.s^{-1}$).
Conclusion: Deep water running was perceived as a more strenuous but comfortable exercise mode for women with large breasts. Increased comfort was attributed to reduced vertical breast velocity rather than reduced vertical breast displacement.

Exercise prescription is fundamental to the practice of sports medicine, not only in the treatment of musculoskeletal disorders, but also in health promotion. The positive health benefits associated with physical exercise are well documented and sports medicine practitioners play a critical role in prescribing physical activity to patients. One target group of patients who frequently seek treatment and require specialised exercise prescription are women with large breasts. These women can be inhibited from participating in activities such as running and jumping due to exercise-induced breast discomfort.[1–10] Previous biomechanical studies of breast motion have related this exercise-induced breast discomfort to excessive breast movement,[1 4–7 9–12] particularly vertical movement, where as little as 2 cm of vertical breast displacement has been sufficient to induce discomfort in women.[4 11]

Deep water running has become an increasingly well recognised form of cardiovascular exercise. It is most commonly used by post-operative patients and athletes recovering from injury, and can even be suitable for patients who are not able to swim. It provides an alternative form of aerobic exercise to land-based running in situations where loading of the musculoskeletal system could be problematic,[13–15] such as in bone and joint injuries and obesity. The benefits of deep water running include aerobic, anaerobic and muscle strength training, at higher physiological responses than treadmill running.[13 16–18] The buoyant forces characteristic of deep water running offer both supportive and assistive forces to the body. We postulated that these buoyant forces might also help to counteract the gravitational forces that accelerate the breasts downward during land-based running and, in turn, could decrease exercise-induced breast discomfort. However, an extensive literature review found no previous studies had systematically investigated the associations among deep water running, breast movement and exercise-induced discomfort. Therefore, to establish whether deep water running could provide an alternative, comfortable form of exercise for women with large breasts, this study aimed to establish whether deep water running reduced exercise-induced breast motion and discomfort in women with large breasts relative to treadmill running. We hypothesised that vertical breast displacement and, in turn, breast discomfort would be reduced when women with large breasts ran in deep water compared to running on a treadmill.

METHODS

Subjects

Sixteen women (mean age = 32 years, range 19–43 years; mean mass = 74.1 kg, range 61–114 kg; mean height = 1.7 m, range 1.61–1.74 m), who were professionally sized to wear a C+ bra cup, were recruited as representative of women with large breasts. The average brassiere band size of the subjects was size 14 (range size 10–18; Australian sizing) and their median cup size was a D cup (range C–J). A table summarising international brassiere sizing conversions can be found in McGhee and Steele.[19] As hormone levels can influence connective tissue within the breasts, only subjects who were premenopausal and not currently breast feeding or pregnant were recruited. Furthermore, participants with a history of previous breast surgery or any musculoskeletal disorder or pain that would inhibit them from running were excluded. All recruiting and testing procedures were approved by the University of Wollongong Human Research Ethics Committee, and all subjects gave written informed consent to participate in the study.

Abbreviations: RPE, rating of perceived exertion; VAS, visual analogue scale

Experimental procedures

The subjects were required to run under two experimental conditions: on a treadmill (PowerJog GX-100; Expert Fitness UK, Bridgend, Mid Glamorgan, UK) and in 2.4 m deep water. Although it is acknowledged that deep water running does not replicate the exact biomechanical or physiological characteristics of land-based or treadmill running,[13 15 20] it was selected as it was postulated to provide a comfortable form of exercise for women with large breasts that did not necessitate the ability to swim and involved gross body movements that were similar to land-based running.

To establish a constant running cadence during the two experimental conditions, each subject first self-selected a treadmill running velocity, which they deemed replicated the velocity they would choose when running for fitness on land. Once established, the stride rate of each subject was timed using a metronome. The pace of each subject's stride rate during both the treadmill and deep water running trials was then standardised using the metronome to ensure the subjects ran at the same stride rate in each experimental condition, as stride rate is known to influence breast motion.[3 9] After sufficient practice to set the stride rate and a familiarisation session of running in the two environments, each subject completed three trials per experimental condition, running for 1 min each trial after reaching a steady state stride rate. Extensive pilot testing confirmed that running for 1 min per trial in deep water was the maximum duration most subjects could maintain a consistent running technique. Immediately after running, the subjects were asked to rate their breast discomfort and breast pain using a visual analogue scale (rated 1–10), as well as their perceived exertion using the Borg scale (rated 6–20).[21]

Breast kinematics

During the treadmill and deep water running trials each subject's breast motion was filmed (25 Hz) using a tripod-mounted, levelled video camera. During the treadmill running trials a Digital Camcorder MV600i digital video camera (Canon Australia Pty Ltd, North Ryde, New South Wales, Australia) was located 2.5 m directly in front of the subject whereas in the deep water trials a Poolcam video camera (Signal Processing Associates, Wantirna, Victoria, Australia) placed in waterproof housing, was located 2.5 m from the subject. Scaling references were placed in the same plane as the subject in both conditions (on the treadmill and weighted down in the water next to the subject) to enable later conversion of the video images to real-life measurements. Markers were drawn as black crosses directly on the exposed skin of the sternum, level with the articulation of the third rib, to track vertical torso displacement. Breast movement was tracked by markers drawn as black crosses directly on the exposed skin of the superior aspect of the breast immediately above the nipple, level with the fourth to fifth rib, and by rigid raised markers (3 mm in diameter) adhered to the subject's nipples (on the skin under their singlet) to make the nipples more prominent. Previous studies have stated that nipple displacement relative to torso displacement is most representative of vertical breast displacement, and that a marker on the superior aspect of the breast moves less than a nipple marker.[7 22] The superior breast marker was eventually used to digitise breast movement in both experimental conditions rather than the nipple marker because the nipple marker often became difficult to see during the water running trials due to bubbles created by breast motion. Therefore, it is acknowledged that breast displacement could be underestimated in the present study.

The subjects wore the same clothing during each experimental condition: tightly fitted cycling shorts, a fine Lycra® singlet with a thin crop top insert (Bonds, Pacific Brands Limited, Hawthorn, Victoria, Australia) and an aqua jogging belt (a standard piece of equipment used in deep water running to assist floatation). The singlet with a crop top was chosen because it provided support similar to that of a swimming costume likely to be worn during deep water running but enabled a relatively clear view of the breast markers in both environments while maintaining subject modesty. The subjects wore their own athletic footwear when running on the treadmill and no shoes when running in the water. Testing was scheduled around each subject's menses to eliminate any possible breast pain effects due to cyclic mastalgia.

Data analysis

The video images of the three running trials per experimental condition for each subject were captured to a personal computer using Pinnacle Studio Deluxe Version 8.3.17 software (Pinnacle Systems, Mountain View, California, USA). The right and left breast landmarks and the sternal landmark were then manually digitised for at least 15 breast cycles per trial using Hu-m-an™ V.3 software (HMA Technology Inc, King City, Ontario, Canada). The marker images were magnified four fold to improve digitising accuracy. Vertical breast displacement relative to trunk (sternum) movement (cm) and vertical breast velocity ($cm.s^{-1}$) were calculated for each subject's right and left breast using custom software (Labview 6, National Instruments Corporation, Austin, Texas, USA).

The vertical breast displacement, peak vertical breast velocity, ratings of perceived exertion, breast pain and discomfort data were analysed using a series of paired Student's t tests to determine whether these variables differed significantly ($p<0.05$) when the subjects ran in the two experimental conditions. Although it is acknowledged that the risk of a Type 1 error is increased when multiple Student's t tests are conducted, the alpha level was not adjusted as the cost of the error was deemed low and the study was considered exploratory. A repeated measures ANOVA design with two factors (condition: treadmill and deep water; peak vertical breast velocity: upward and downward) was also used to determine the effects of running environment on the components of breast velocity. All statistical analyses were computed using SPSS for Windows software V.11.5.0 (SPSS Inc, Chicago, Illinois, USA).

RESULTS

Breast pain, discomfort and ratings of perceived exertion

Mean ratings of exercise-induced breast pain, breast discomfort and perceived exertion for the two experimental conditions are displayed in figs 1 and 2. When running in deep water, the subjects reported significantly less exercise-induced breast pain

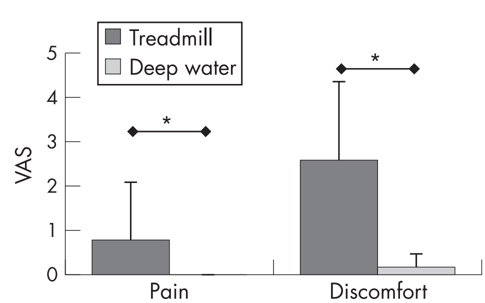

Figure 1 Exercise-induced breast pain and discomfort rated by the subjects (n = 16), using a visual analogue scale (VAS; scale 0-10), immediately after running on the treadmill and in the deep water. *Indicates a significant ($p<0.05$) difference between the two conditions.

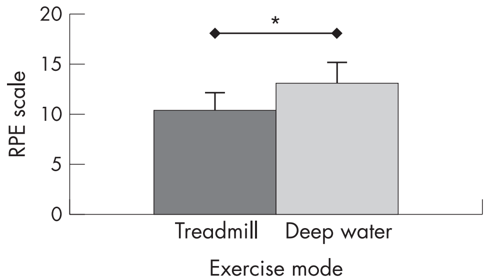

Figure 2 Rating of perceived exertion (RPE; scale 6–20) reported by the subjects (n = 16) immediately after running on the treadmill and in the deep water. *Indicates a significant ($p<0.05$) difference between the two conditions.

(mean (SD) 0 (0.00)) and discomfort (0.1 (0.25)) compared to when running on the treadmill (0.78 (1.3), $t = 2.3$, $p<0.03$ and 2.5 (1.75), $t = 5.5$, $p<0.01$, respectively). In fact, all of the subjects rated breast pain during deep water running as zero on the visual analogue scale. The subjects displayed a significant increase in perceived exertion when running in deep water (13 (2.0), $t = -6.70$, $p<0.01$) compared to treadmill running (10.2 (1.6), $t = -6.7$, $p<0.01$).

Vertical breast motion

Irrespective of experimental condition, both the right and left breasts of the subjects moved in a sinusoidal pattern during running, although the sinusoidal pattern was generally more "erratic" during deep water running. During treadmill running the pattern was consistent and regular (see fig 3). There was no significant difference in vertical breast displacement between the left and right breasts of the subjects in either environment (treadmill: right: 3.2 (1.3) cm, left: 3.5 (1.4) cm, $t = -1.64$, $p = 0.14$; deep water: right: 2.7 (1.1) cm, left: 2.5 (1.0) cm, $t = -1.13$, $p = 0.28$), so movement of the right breast only was used to compare between-condition differences in vertical breast displacement. Although extensive efforts were made to ensure the women ran at the same stride rate during the two experimental conditions, retrospective video analysis indicated that the stride rate was, on average, significantly greater during deep water running (67.0 (3.7) strides per min, $t = -2.60$, $p<0.02$) relative to treadmill running (62.7 (8.0) strides per min). It is acknowledged that self-selected stride rates in the present study were relatively low compared to stride rates typically reported in the literature (eg, 85 strides per min for elite male runners).[24] However, it is speculated that this was a strategy adopted by these women to minimise exercise-induced breast discomfort when running on the treadmill.

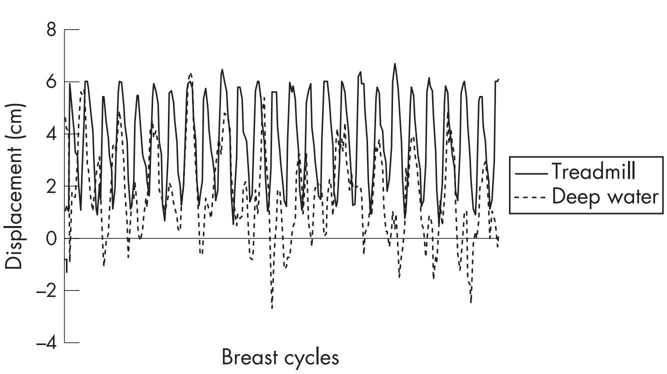

Figure 3 Sinusoidal pattern of vertical breast displacement (cm) of the right breast displayed by a representative subject during treadmill running (solid line) and deep water running (dashed line). The pattern of breast motion was less consistent when running in deep water relative to running on the treadmill.

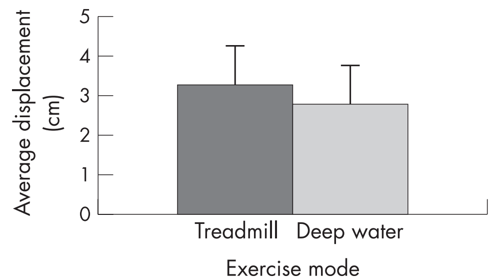

Figure 4 Mean vertical breast displacement (cm) displayed by the subjects (n = 16) when running on the treadmill and in deep water. There was no significant difference between the two conditions.

Mean vertical breast displacement and peak vertical breast velocity of the right breast during the two experimental conditions are displayed in figs 4 and 5, respectively. In contrast to the original hypothesis, there was no significant difference in the mean (SD) vertical breast displacement during deep water running (2.8 (1.1) cm) compared to treadmill running (3.3 (1.1) cm, $t = 0.75$, $p = 0.47$; see fig 4). However, when running in deep water there was a significant reduction in the mean (SD) upward (29.7 (14.0) $cm.s^{-1}$, $p<0.01$) and downward (31.1 (17.0) $cm.s^{-1}$, $p<0.01$) peak vertical breast velocities when running in deep water compared to treadmill running (upward: 81.4 (21.7) $cm.s^{-1}$, $p<0.01$; downward: 100.0 (25.0) $cm.s^{-1}$, $p<0.01$; see fig 5). The reduction in mean peak vertical breast velocity during deep water running was most evident in the downward direction and could not be related to a lower stride rate during the water running, as the stride rate during the water running was found to be greater than during the treadmill running.

DISCUSSION

Breast pain, discomfort and ratings of perceived exertion

Previous research has established that ratings of exercise-induced breast pain and discomfort are lower when women wear highly supportive brassieres compared to wearing low support brassieres.[4–6 9 22] No previous investigations have measured breast discomfort experienced by women during aquatic exercise. In the present study all subjects reported that both exercise-induced breast discomfort and breast pain were lower when they ran in deep water compared to running on a treadmill. The slow stride rate adopted by the subjects during treadmill running (62.7 strides per min) is speculated to be a strategy used by the subjects to minimise breast discomfort.

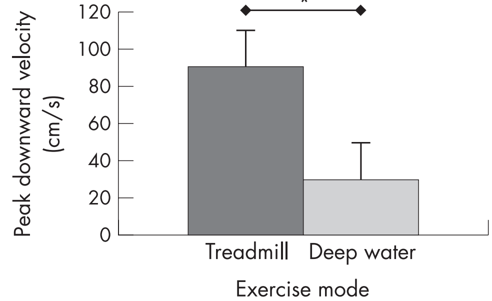

Figure 5 Mean peak downward breast velocity ($cm.s^{-1}$) displayed by the subjects (n = 16) when running on the treadmill and in deep water. *Indicates a significant ($p<0.05$) difference between the two conditions.

What is already known on this topic

- Women with large breasts can be inhibited from participating in land-based running due to exercise-induced breast discomfort caused by excessive breast movement.
- Deep water running provides an alternative form of aerobic exercise in which the buoyant forces might help to counteract the gravitational forces that accelerate the breasts downward during land-based running.

What this study adds

- Women with large breasts perceived deep water running as a strenuous but more comfortable form of exercise relative to running on a treadmill.
- The reduction in exercise-induced breast pain was attributed to a reduction in vertical breast velocity rather than any change in vertical breast displacement.

As originally postulated, the buoyant forces associated with running in an aquatic environment appeared to significantly reduce exercise-induced breast pain and discomfort, while providing additional resistance to significantly increase the ratings of perceived exertion. Therefore, deep water running was perceived by these women with large breasts to provide a more strenuous, but more comfortable form of exercise relative to running on a treadmill.

Vertical breast motion

The pattern of breast motion and the mean and range of vertical breast displacement during the treadmill running was consistent with previous studies.[1 4–7 9] The breast motion pattern was sinusoidal during both the treadmill and deep water running, however it was more ''erratic'' during the deep water running. This was attributed to the fact that water running was a novel activity for every subject and, despite extensive familiarisation, the subjects displayed poorer movement quality and a less consistent synchronisation of the limbs, trunk and breasts during deep water running compared to the treadmill running.

We originally hypothesised that any decrease in exercise-induced breast discomfort associated with deep water running would be due to a reduction in vertical breast displacement, as previous research of treadmill running has associated reductions in breast pain and discomfort with reduced vertical breast displacement achieved with highly supportive brassieres.[1 4–9 12 23] However, in contrast to this hypothesis, there was no significant between-condition difference in vertical breast displacement. Instead, a significant between-condition difference in peak vertical breast velocity was identified.

Vertical breast velocity

Within the limited published literature pertaining to breast motion, most previous research has examined vertical breast displacement rather than velocity during treadmill running.[1 4–7 9 10] In fact, only 2 of the 11 biomechanical studies of breast movement located in the literature have documented breast velocity during treadmill running.[4 9] The absolute breast velocities during treadmill running in the present study were consistent with those reported by Shivitz[9] of 50–100 $cm.s^{-1}$ for 17 women with large breasts (C and D cup size) running on a treadmill at 9.6 $km.hr^{-1}$. However, those reported by Gehlsen and Albohm[4] of 18.15 (6.65) $cm.s^{-1}$ for 20 women of varying breast size (34B–36D USA sizing) running on a treadmill at 11.2 $km.hr^{-1}$, were vastly different. This could be explained by between-study differences in the methods used to calculate breast velocity. Gehlsen and Albohm[4] averaged two breast cycles to calculate breast velocity whereas the instantaneous velocity of 30 and 90 cycles was averaged in the present study and in the Shivitz[9] study, respectively.

No previous research has reported vertical breast velocity during deep water running or any other form of aquatic exercise. In the present study mean peak vertical breast velocity was significantly less during deep water compared to treadmill running. The mean peak vertical breast velocity during deep water running was similar in the upward and downward direction (30 $cm.s^{-1}$; see fig 4). However, during treadmill running it increased from 80 $cm.s^{-1}$ in the upward direction to 100 $cm.s^{-1}$ in the downward direction. Haycock[3] described this downward motion of the breasts during running as ''slapping against the chest wall''. It is therefore not surprising that women with large breasts find land-based running, particularly when poorly supported, uncomfortable.

The decrease in exercise-induced breast discomfort and pain evident during deep water running was attributed to the significant reduction in mean peak vertical breast velocity, which was three times less than during treadmill running. Vertical breast displacement, in contrast, was not significantly different, as originally hypothesised. When interpreting this finding it is important to highlight the biomechanical differences when running in the two environments.[13 20] During treadmill running, breast motion was very consistent and synchronised with heel strike, such that the breasts consistently ''slap'' against the chest wall at heel strike. In contrast, during the deep water running there was no heel strike and the motion was more erratic. Despite similar vertical breast displacements, the breasts did not reach their end of range in the downward direction during the deep water running as they started off in a far more elevated position compared to the treadmill running trials, due to the buoyant forces of the water. The buoyant forces also limited the peak downward breast velocity, preventing the breasts from ''slapping against the chest'' and, in turn, decreased exercise-induced breast discomfort and pain typically associated with land-based running.

CONCLUSION

It was concluded that deep water running was perceived as a strenuous but more comfortable form of exercise for women with large breasts relative to running on a treadmill, significantly reducing exercise-induced breast pain and discomfort, while providing additional resistance to significantly increase the ratings of perceived exertion. Deep water running is therefore considered a suitable form of exercise for sports medicine practitioners to prescribe to patients with large breasts. The reduction in exercise-induced breast pain was attributed to a reduction in peak vertical breast velocity, particularly in the downward direction, rather than any change in vertical breast displacement.

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COMMENTARY

The paper provides novel information that further explores the aetiology of breast pain during running in large-breasted women. The knowledge that velocity of breast motion not displacement magnitude as previously thought will inform future bra design for land-based running. In addition, the paper gives support to the prescription of water-based running for large-breasted women.

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